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INFLUENCE OF CALCIUM CHLORIDE ($CaCl_2$) ON THE STRENGTH CHARACTERISTICS OF SAND-BENTONITE MIXTURES.

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Abstract – Sand-Bentonite mixtures have been used as barrier/liner material in many engineering applications such as cores of earthen dams, landfill, cut-off walls and also in hydraulic containments such as reservoirs. The present study focuses on the influence of Calcium Chloride ($CaCl_2$) on the strength characteristics of Sand-Bentonite mixtures. In this study, the Atterberg limits, strength characteristics of sand-bentonite mixtures are investigated for different percentage compositions of sand, bentonite and also for different percentage addition of $CaCl_2$ to support recommendation for a cost-effective liner/barrier material. A series of modified compaction tests and direct shear tests for strength characteristics were conducted on different sand-bentonite mixtures and sand-bentonite-$CaCl_2$ mixtures. The mixtures were formed by mixing the locally available Godavari river sand with sodium bentonite in the percentage replacement of 0%, 15%, 30%, 45% by dry weight of sand. Later $CaCl_2$ in the proportions of 0%, 0.5%, 1.0%, 1.5% is added to the optimum of the sand-bentonite mixtures. The optimum sand-bentonite-$CaCl_2$ mixture is cured for 1 day, 7 days, 14 days and tested for its shear strength parameters. From the laboratory test results it was found that Sand-Bentonite mixture of S:B(70:30) with 1% addition of $CaCl_2$ has the optimum strength parameters.

Index Terms -Sand-Bentonite mixture, Sodium Bentonite, Strength Characteristics, Calcium Chloride, Direct Shear test.

1. INTRODUCTION

Sand mixed with a certain amount of clay or bentonite has been a common practice since a long time for creating mixtures that have a wide range of engineering applications such as Landfill liners, Cores of Earthen dams, Cutoff walls and also in hydraulic containments like reservoirs. The mixture of Sand and Bentonite is able to provide the low permeability or low hydraulic conductivity as required by varying the bentonite content of the mixture. This is because of the ability of bentonite to swell and fill the voids between the sand particles. The sand-bentonite mixture is a solution which is economical for the applications in engineering field where sandy soils are available locally. For the purpose of design, the various properties and strength characteristics of the materials used i.e., sand and bentonite should be studied in order to select the suitable and economical proportion of the mixture which meets the requirements. Since the sand-bentonite mixtures are used in applications involving chemicals like landfill liners, they need to be studied to ascertain how they react and how their properties and strength characteristics change when treated with chemicals like Calcium Chloride.

2. MATERIALS USED AND METHODOLOGY

2.1 Materials used in the present study

2.1.1 Sand

In sand used in the present study is collected from the Godavari river. The sand passing through the 4.75 mm sieve and retained on the 75 micron sieve is used for the present study. This sand was subjected to various laboratory tests as per IS codes to determine the various properties. The results are as given below.

Property	Value
Specific Gravity	2.65
Fines content (<75μm)	3.5
Coefficient of Uniformity, C_U	3.25
Coefficient of Curvature, C_C	1.13
Effective size of particle, D_{10}(mm)	0.12
Maximum Dry Density (gm/cc)	2.03
Optimum Moisture content (%)	8.24
Cohesion,C (kg/cm^2)	0
Angle of internal friction	35.2^o

2.1.2 Bentonite

The Bentonite used for the study was Sodium Bentonite which is naturally occurring hydrated aluminium silicate clay. It exhibits extremely highswelling and water absorbing properties. Bentonite used in this study is sodium bentonite purchased from a supplier in Hyderabad. The bentonite is subjected to various laboratory tests as per IS codes to determine the various properties and results are as given below.

Property	Value
Liquid limit (%)	306
Plastic limit (%)	50.51
Plasticity Index (%)	255.49
Specific Gravity (gm/cc)	2.54
Clay content (%)	51.8
Silt content (%)	44.5
Free Swell Index (%)	590

2.1.3 Calcium Chloride ($CaCl_2$)

Calcium chloride is an inorganic compound, a salt with the chemical formula $cacl_2$. It is colorless crystalline solid at room temperature, highly soluble in water.

Property	Value
Molar Mass	$110.98 g.mol^{-1}$
Appearance	White Powder
Odor	Odorless
Density	$2.15 g/cm^3$
Melting Point	772-775°C
Boiling Point	1935°C

2.2 Proportions of the Sand-Bentonite mixtures

Godavari sand is mixed with bentonite in different proportions. The Atterberg limits, compaction behaviour and the shear strength parameters of the mixtures are studied. The mixture proportions are as follows.

Sample Name	Proportion of Materials used
S:B (100:0)	100% Sand + 0% Bentonite
S:B (85:15)	85% Sand + 15% Bentonite
S:B (70:30)	70% Sand + 30% Bentonite
S:B (55:45)	55% Sand + 45% Bentonite

Calcium Chloride is added to the optimum of the above mixtures in the percentage of 0.5%, 1.0%, 1.5%.

2.3 Methodology

The Atterberg limits, Maximum Dry density, Optimum moisture content, Shear strength parameters for the mixtures of Sand-Bentonite are determined from the laboratory tests. Based on these results obtained, the optimum mixture of the Sand-Bentonite is selected. For the above obtained optimum mixture, Calcium Chloride is added in the percentages of 0.5%, 1.0%,1.5% of dry weight of the mixture. The Atterberg limits, MDD, OMC, Shear strength parameters of the mixtures are determined from the laboratory experiments. The optimum mixture is chosen based on the results and the shear strength parameters for 1day, 7 days, 14 days are determined.

3. LABORATORY EXPERIMENTS CONDUCTED

3.1 Atterberg limits

The Atterberg limits of bentonite and the sand-bentonite mixtures are determined in the laboratory as per IS 2720 (Part-5)

3.2 Modified proctor compaction test

Modified proctor test was carried out on the specimens as per IS 2720 (Part 8) 1980. The compaction curves for sand-bentonite mixture were obtained and the OMC and MDD values of the different mixtures are determined. Based on this test we can determine how the OMC and MDD values of the mixtures change with bentonite content of the mixtures.

3.3 Direct Shear test

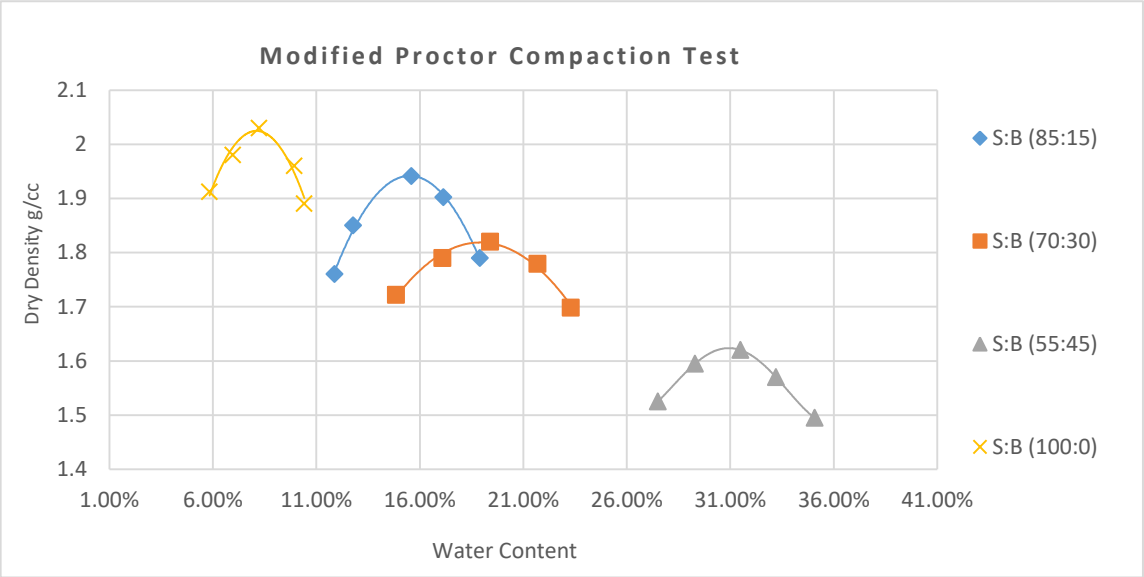
Direct shear tests were performed according to IS 2720 (part 13)-1986 on the Godavari sand and the Godavari sand mixed with different proportions of bentonite clay. The tests were conducted on three different normal stresses i.e., 0.3 Kg/cm^2 , 0.5 Kg/cm^2, 0.7 Kg/cm^2. The angle of internal friction and cohesion values were obtained by plotting a straight line through the plot of shear stress versus the normal stress.

4. RESULTS AND DISCUSSIONS

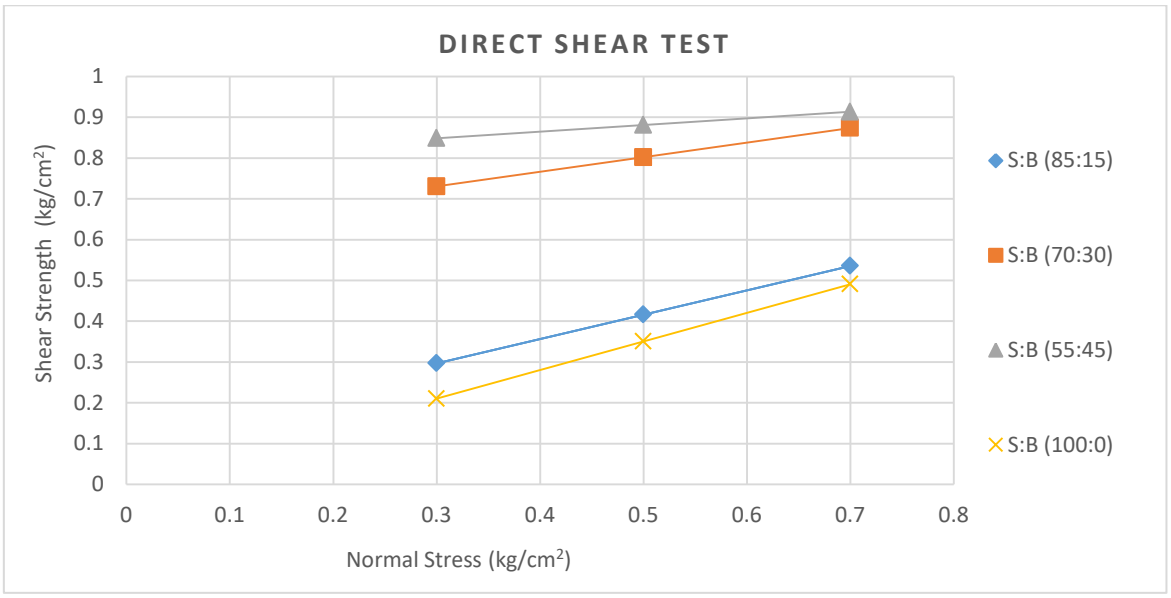
The different proportions of sand-bentonite mixtures are tested for Atterberg limits, Modified Proctor Compaction test, Shear strength parameters. The laboratory test results are tabulated below.

Proportion	**S:B (100:0)**	**S:B (85:15)**	**S:B (70:30)**	**S:B (55:45)**
Liquid limit	NP	41.8%	84.7%	148.2%
Plastic limit	NP	16.8%	29.7%	38.11%
Plasticity Index	NP	24.9%	55.0%	110.1%
M.D.D(g/cc)	2.03	1.941	1.82	1.62
O.M.C	8.24%	15.6%	19.4%	31.5%
Cohesion(Kg/cm^2)	0	0.118	0.623	0.807
Angle of Internal friction	35.2	30.81	19.7	9.2

The Compaction curves of the Sand-Bentonite mixtures as per the laboratory test data are compared in the graphical data below.



The Shear strength parameters of the different sand-bentonite mixtures are compared in the graphical data below.

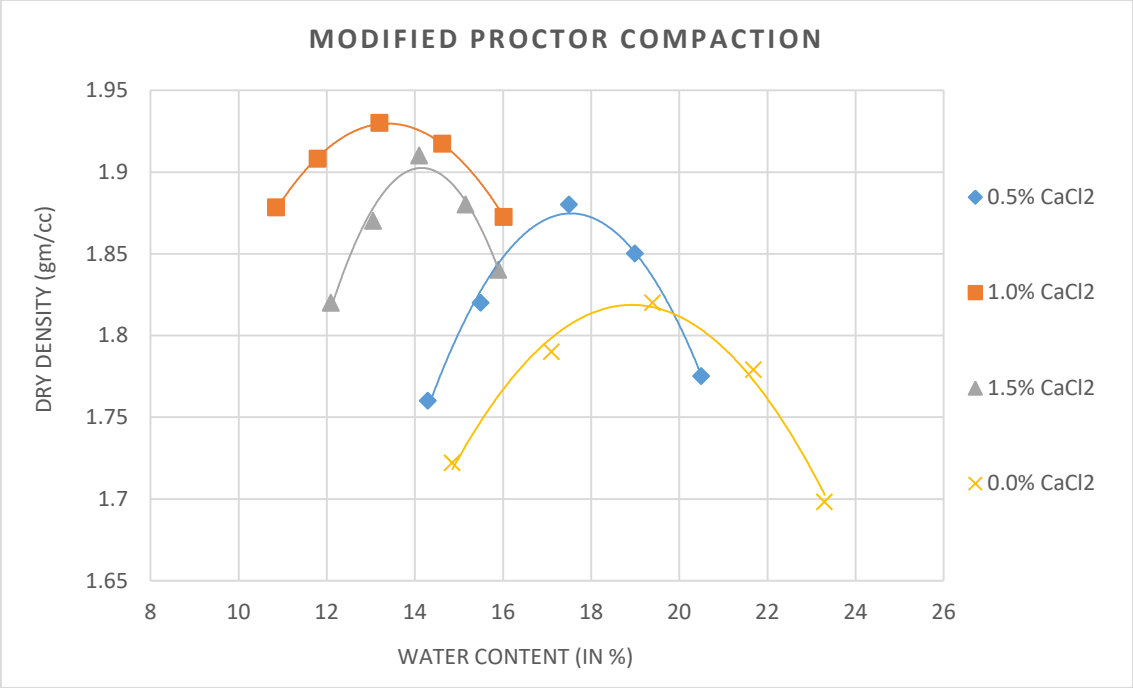


Based on the above comparison of data of the modified compaction test data and the shear strength parameters, optimum sand-bentonite mixture was found to be S:B (70:30).

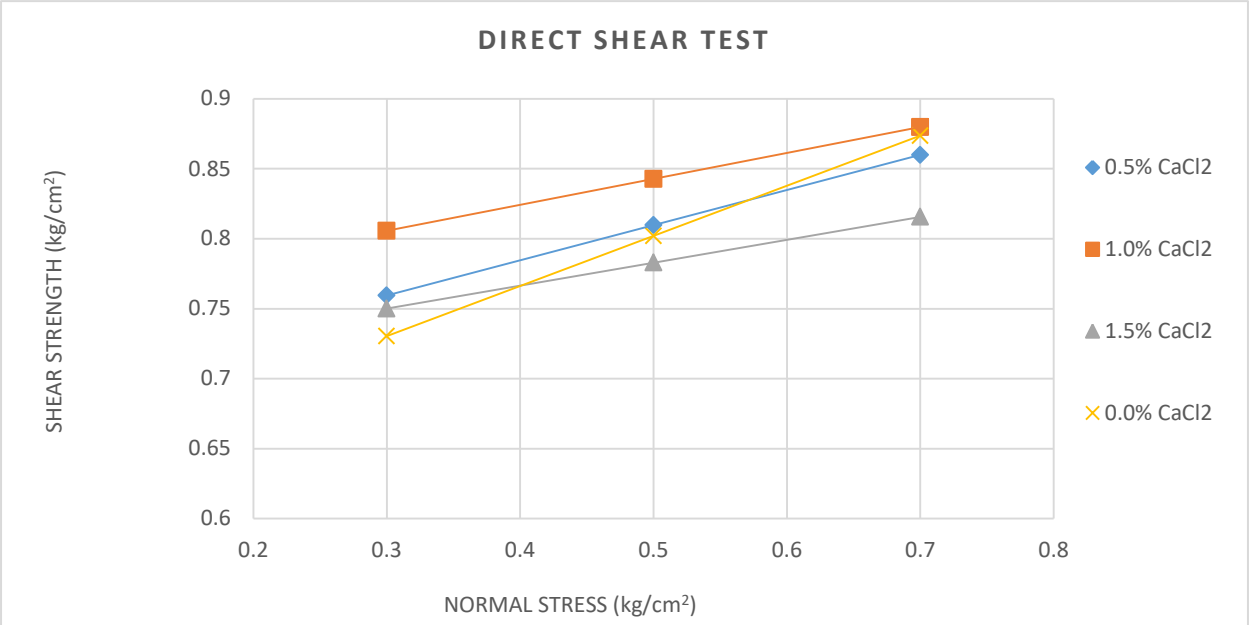
The Calcium Chloride was added to the sand-bentonite mixture of S:B(70:30) in the percentages of 0.5%, 1.0%, 1.5%. The calcium chloride added sand-bentonite mixtures are tested for Atterberg limits, modified proctor compaction test, shear strength parameters. The laboratory test results are tabulated below.

Percentage of $CaCl_2$	0.0%	0.5%	1.0%	1.5%
Liquid limit	84.7%	79.4%	70.6%	62.3%
Plastic limit	29.61%	34.6%	38.9%	42.2%
Plasticity Index	55.03%	44.8%	31.7%	20.1%
O.M.C	19.40%	17.5%	13.2%	14.1%
M.D.D (gm/cc)	1.82	1.88	1.93	1.91
C (Kg/cm^2)	0.623	0.684	0.750	0.701
PHY	19.7	14.1	10.5	9.3

The Compaction curves of the calcium chloride added sand-bentonite mixtures are compared in the graphical data below.

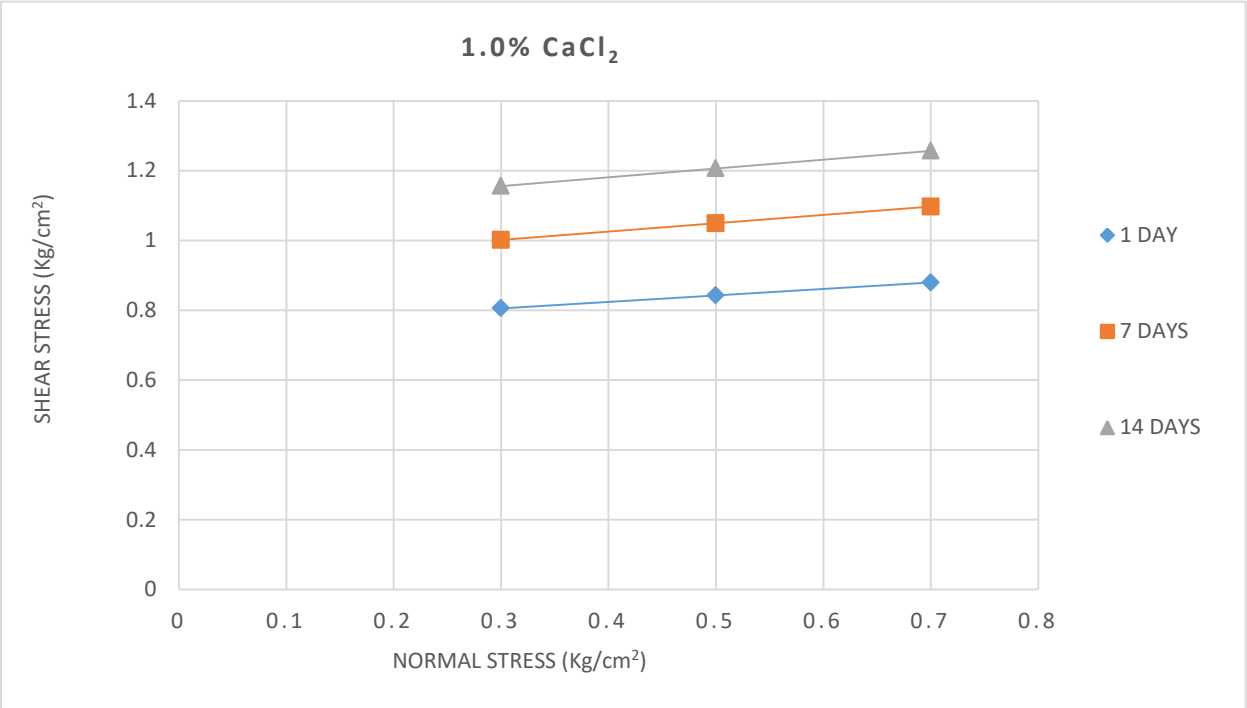


The Shear strength parameters of the calcium chloride added sand-bentonite mixtures are compared in the graphical data below.



Based on the above comparison of the modified compaction test data and the shear strength parameters, the sand-bentonite mixture of S:B(70:30) with 1.0% addition of $CaCl_2$ was found to be optimum.

The Optimum sand-bentonite mixture of S:B(70:30) with 1.0% addition of $CaCl_2$ was cured for 1day, 7days, 14days and was tested for shear strength parameters. The shear strength test data is as follows.



5. CONCLUSION

From the results of investigations following conclusions can be drawn.

1. The Maximum dry density decreased with increase in the bentonite content of the mixtures.
2. The optimum moisture content of the mixtures increased with increase in the bentonite content of the mixture.

3. The sand-bentonite mixture S:B(85:15) has the more M.D.D but has less shear strength hence it is not the optimum. The sand-bentonite mixture S:B(70:30) has both moderate M.D.D and moderate shear strength hence it has been chosen as the optimum mixture.
4. Addition of Calcium Chloride caused a decrease in the liquid limit and increase in the plastic limit of the mixture.
5. The maximum dry density of the mixture increased with increase in the percentage of $CaCl_2$ till 1.0% and then decreased for 1.5% addition of $CaCl_2$
6. The direct shear test results on S:B(70:30) mixtures with addition of $CaCl_2$ show that the mixture with 1.0% addition of $CaCl_2$ attains optimum shear strength properties.

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